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SEPARATION OF COMMINGLED PLASTICS
BY SELECTIVE DISSOLUTION

BY

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INTRODUCTION

Plastics are an increasingly large component of household waste and offer great potential for resource and energy recovery through recycling. The typical household waste would be primarily composed of the following plastics : polyvinyl chloride (PVC), polystyrene (PS), low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP) and polyethylene terephthalate (PET). These components are separable from the mixed waste streams through bottle recycling programs and hand sorting. However problems remain even when these streams are separated from metals, cellulose, and other wastes. The major difficulty is that the plastics themselves are mixtures. This problem is of an increasing complexity with the advent of multi-layered containers.

Most pairs of polymers are incompatible and form two phases upon mechanical mixing. This incompatibility typically leads to poor physical properties unless one of the components is microdispersed in the other. To this end incentives exist to separate waste plastic streams into pure polymers or at least render innocuous certain components that may cause difficulties in fabrication or lead to poor physical properties in a mechanical blend. The same thermodynamic differences that cause incompatibility provide an opportunity to separate the components of the mixed plastic waste stream. In principle, a mixed plastics stream can be separated into pure components by selective dissolution followed by flash devolatilization and compositional quenching.

OVERVIEW OF PROCESS

Figure 1 illustrates the basic flow diagram of the polymer reclamation process. We will use available technology for the collection and shredding of the mixed waste stream. We have assumed collection and shredding to be outside the battery limits of our operation. The commingled polymers will be separated using a controlled sequence of solvents and solvation temperatures. Dissolution is fast at low polymer concentrations, say 10% by weight or less. At these low concentrations, the viscosity will also be low making filtration feasible. The filtration step will be used to remove insoluble contaminants such as metals, glass, cellulose and some pigments. Since the polymers are in solution this affords an opportune time to add stabilizers and impact modifiers.

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Once separated, flash devolatilization combined with conventional devolatilization techniques will be used to produce solvent free polymers. Flash devolatilization and compositional quenching will also microdisperse minor components and impurities rendering them innocuous. When selective dissolution is used in conjunction with flash devolatilization and compositional quenching, the resulting polymers will exhibit near first pass physical properties. Another key feature of this process is the internal solvent recycle which alleviates both the economical and environmental concerns of a solvent based process.

FLASH DEVOLATILIZATION

This polymer reclamation technology evolved through a natural progression from our work involving the impact modification of polymers via compositional quenching¹⁻⁶. This is where two incompatible polymers are dissolved in a common solvent to form a homogeneous mixture. Phase separation occurs when the solvent is rapidly removed by flash devolatilization. The devolatilization step is fast and it plunges the residual, polymer/polymer/solvent mixture deep into a region of two phases. Phase separation occurs by spinodal decomposition and generates a microdispersion with a characteristic and small phase separation distance. If one of the phase volumes is small, a uniformly sized dispersion will result.

Low solids flash devolatilization is a relatively simple process which is readily scalable. An experimental apparatus is depicted in figure 2. The dissolution step is typically batch, but the flash devolatilization process is continuous thereafter. The polymer concentrations are typically 5-10% by weight. The feed solution is metered into a heat exchanger by a positive displacement pump. The pressure is maintained sufficiently high to ensure that no boiling occurs. This pressure is regulated by a back-pressure or flash valve and is constrained at a minimum value, typically 10-40 atm. The temperature upstream of the flash valve, typically 200-300°C, is one of the independent variables that governs the devolatilization step. The flash chamber pressure, typically 5-100 torr, is the other independent variable. Together they determine the polymer concentration after the flash, typically 60-95%, and the after flash temperature, typically 0-100°C. To a first approximation, the flash achieves vapor-liquid equilibrium.

750 Torr = 1 atm

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SELECTIVE DISSOLUTION

Figure 3 illustrates a typical bench scale dissolution apparatus. The commingled plastic waste, typically 25 kg, is placed in the dissolution column with screen packs at both ends. A stirred vessel would be preferred but a column is a suitable substitution on this scale due to its ease of fabrication. A gear pump is used to circulate solvent, typically 20 liters, through the heat exchanger and dissolution column. Selective dissolution is performed in the sequential batch mode. A unique temperature for a given solvent is used to selectively extract a single polymer group from the commingled stream. The polymer obtained from a single extraction is isolated via flash devolatilization. The recovered polymer is pelletized, while the recovered solvent is returned to the dissolution reservoir to extract the next polymer group at a higher temperature. It is this series of controlled temperature-solvent extractions which facilitates the separation of individual polymers from a commingled waste stream.

Tetrahydrofuran (THF) was selected as our first trial solvent due to the vast data base accumulated in prior compositional quenching work. A commingled polymer sample was prepared using equal volumes of virgin polymers from the major packaging groups : PVC, PS, PP, LDPE, HDPE, and PET. Figure 4 illustrates a split obtained using THF as the dissolution solvent. The first extraction was performed at 25°C, with the product consisting of 99% of the PVC and PS as a commingled blend. The second cut extracted 99% of the LDPE at 70°C. The third cut consisted of 99% of the PP and HDPE as a commingled blend at 160°C. The final cut recovered 99% of the PET at 190°C. Physical property evaluations are currently being conducted.

CONCLUSIONS

Although this project is in its infancy, initial results are very promising. When fully developed, this technology may be one of the key answers to polymer reclamation. Using THF we have demonstrated a four way split of the six major packaging plastics. Preliminary indications are that solvents exist to separate cleanly all six major plastic groups. With greater than 99% separation efficiencies, compositional quenching will microdisperse the minor components and render them innocuous. It is believed that the split which contains the PP and HDPE will exhibit good physical properties. We do not expect

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the same for the PVC and PS split. If THF is to be used as the dissolution solvent, a second solvent, eg. methylene chloride, can be used to extract the PS prior to the room temperature THF extraction.

Efforts are currently under way to determine the dissolution characteristics for a true commingled waste stream. Due to the variation in molecular weight, branching, and copolymers among manufacturers, we anticipate that separation efficiencies will be lower for actual waste streams. We expect that compositional quenching will overcome the potential problems which may result from the reduced efficiencies. Problems which also may occur due to insoluble contaminants and soluble contaminants will also be addressed. Preliminary economics show that application of this technology on a scale of 50 MM pounds per year scale can be accomplished for less than 15 cents per pound. The next stage is the design of a nominal 100 pound per hour pilot plant.

NOMENCLATURE

HDPE	High density polyethylene
LDPE	Low density polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
THF	Tetrahydrofuran

ACKNOWLEDGEMENTS

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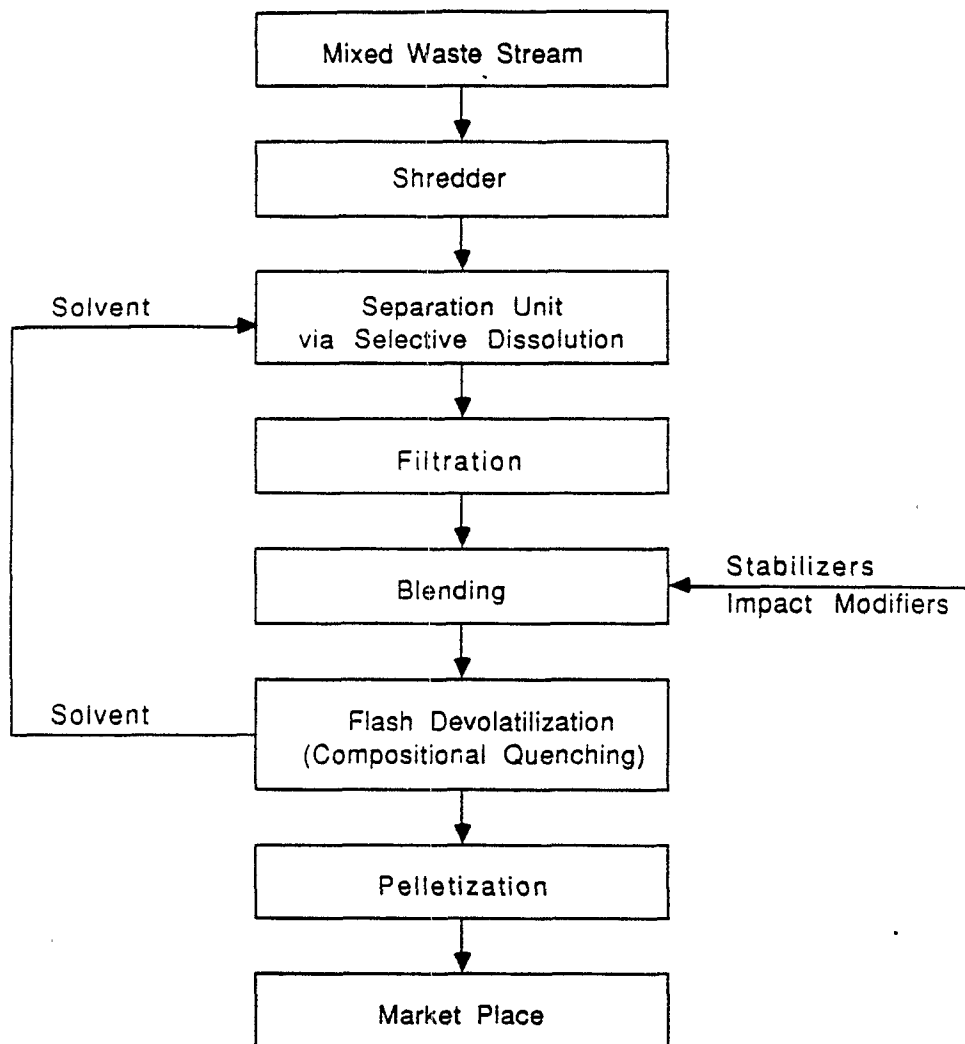
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FIGURE 1: PROCESS FLOW CHART



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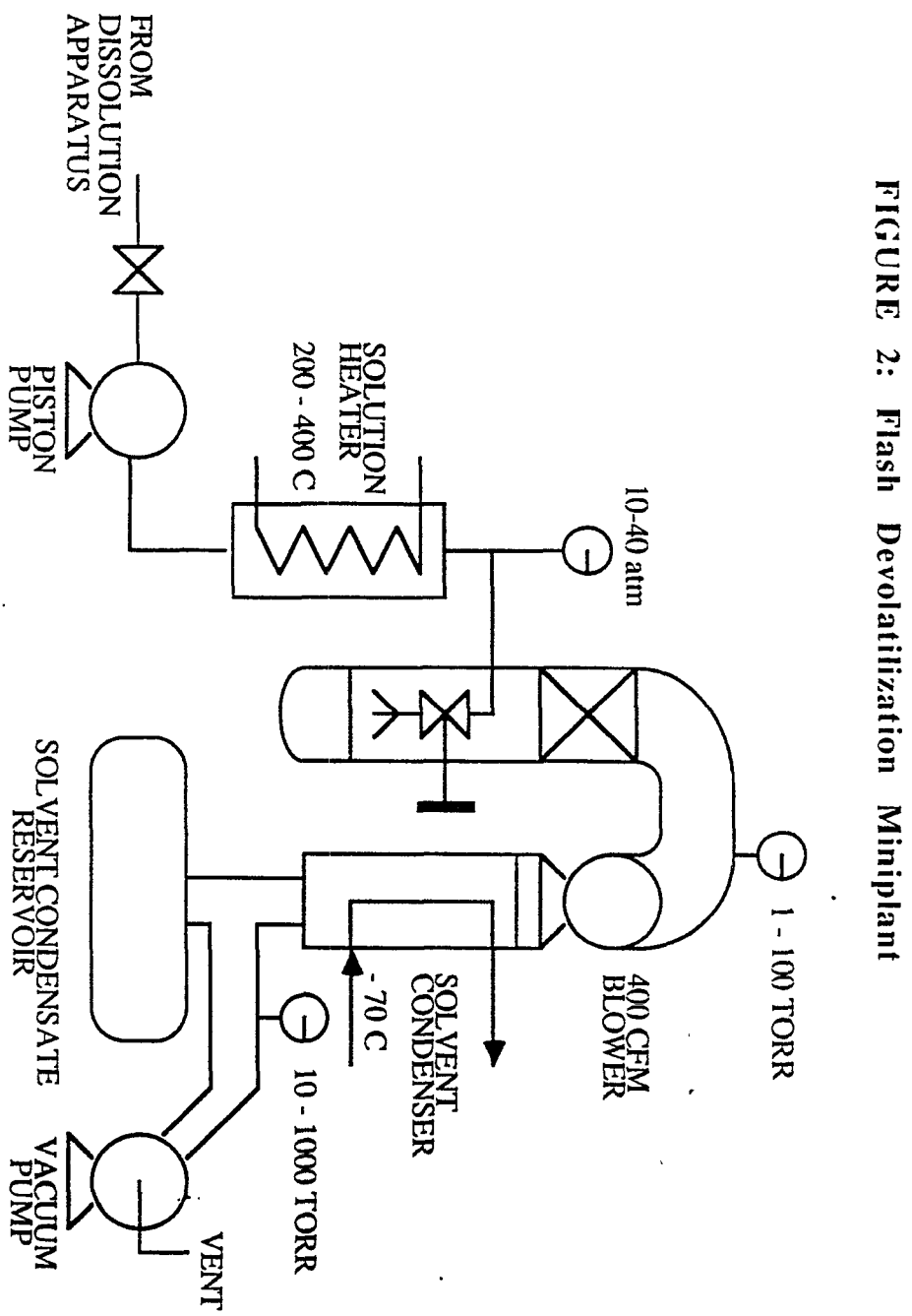
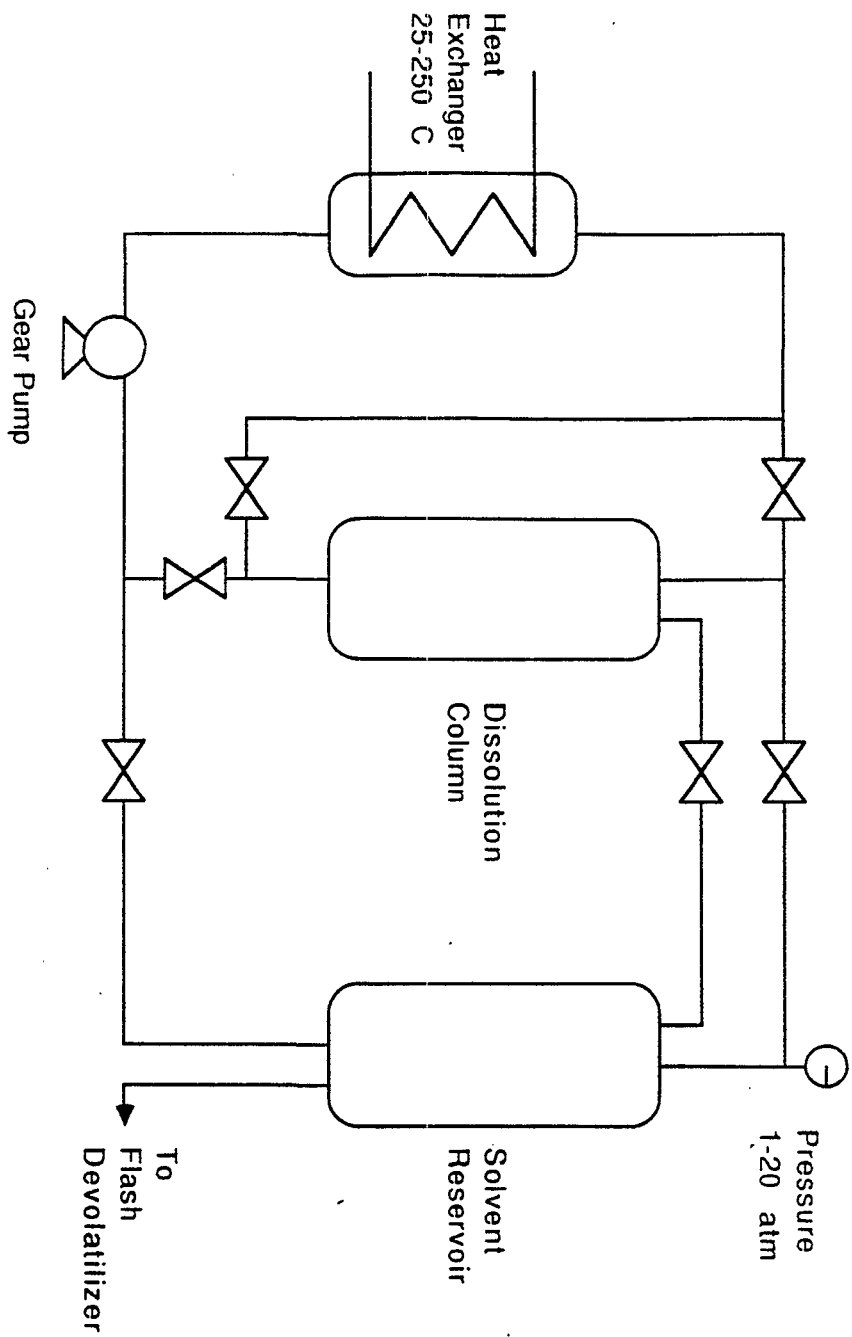


FIGURE 2: Flash Devolatilization Miniplant

FIGURE 3: Dissolution Apparatus



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**FIGURE 4: SELECTIVE DISSOLUTION USING
TETRAHYDROFURAN**

First Cut: Room Temperature

PVC >99%

PS >99%

Second Cut: 70°C

LDPE >99%

Third Cut: 160°C

PP >99%

HDPE >99%

Fourth Cut: 190°C

PET >99%

- Experiments were conducted with virgin polymers.
- Extraction percents were measured using a gravimetric technique.

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About the authors

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